NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF:

March 27, 1971

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned
U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,337,790

Corporate Source : ~~Jet Propulsion Laboratory~~ GP

Supplementary
Corporate Source : Stanford Research Institute

NASA Patent Case No.: XNP-02251

Please note that this patent covers an invention made by an employee of a NASA contractor. Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of. . . ."

Gayle Parker

Enclosure:
Copy of Patent

N71-20896

Aug. 22, 1967 JAMES E. WEBB 3,337,790
ADMINISTRATOR OF THE NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
MERCURY CAPILLARY INTERRUPTER
Filed Feb. 11, 1965

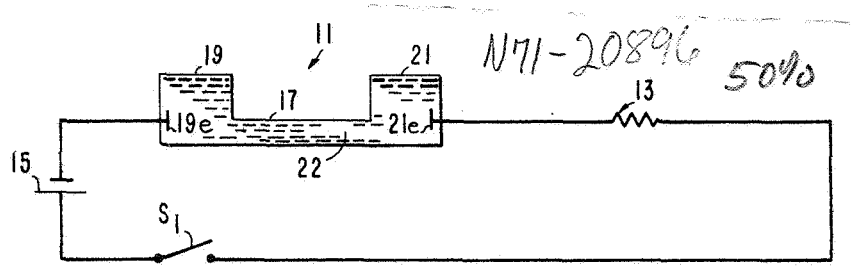

FIG. 1

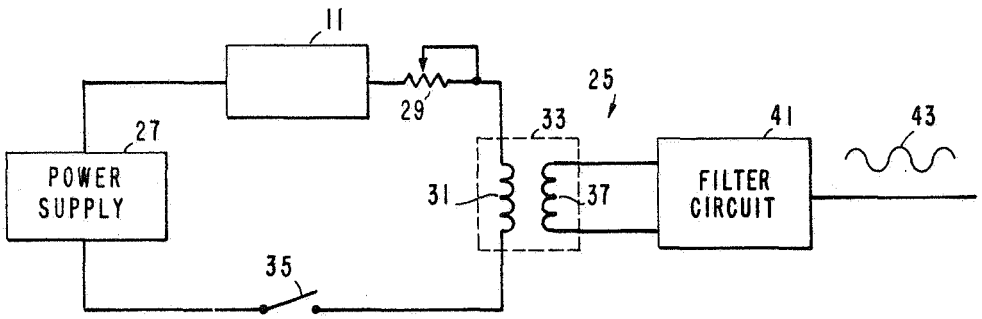

FIG. 2

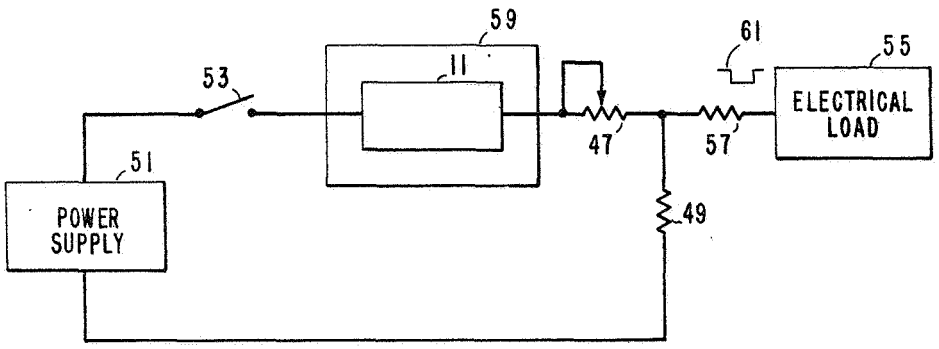

FIG. 3

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1207

United States Patent Office 3,337,790 Patented Aug. 22, 1967

3,337,790

MERCURY CAPILLARY INTERRUPTER

James E. Webb, Administrator of the National Aeronautics and Space Administration, with respect to an invention of Clarence H. Heckler, Palo Alto, Calif.

Filed Feb. 11, 1965, Ser. No. 432,030
4 Claims. (Cl. 321—48)

ABSTRACT OF THE DISCLOSURE

An interrupter consisting of a capillary tube, filled with current-conducting liquid, such as mercury, with electrodes on opposite ends of the tube, for connecting the interrupter to associated circuitry. When current flows between the electrodes through the liquid, the liquid tends to heat up, vaporizing at about the center of the capillary tube, and thereby interrupting the flow of current therethrough. Upon the interruption of the flow of current, the vapor, trapped within the tube between liquid sides, condenses back to liquid form to provide a subsequent continuous path for current flow. The rate of interruptions is a function of the properties of the current-conducting liquid, the magnitude of the current and the dimensions of the capillary tube.

Origin of invention

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 U.S.C. 4257).

This invention relates to an electrical interrupting circuit and, more particularly, to an improved electrical switching device utilizing a current-conducting liquid.

Various switching devices and techniques are employed to selectively energize circuits or systems at selected rates, in order to control their manner of operation. Multicontact relays extensively used for such purposes, are but one example. By controlling the rate and manner at which the coil of a relay is energized, the flow of current through different ones of the multiple contacts is controlled. Similar devices, known as current interrupters or vibrators are used to convert direct current (D.C.) energy into alternating current (A.C.) energy for driving the many circuits which require A.C. energy for their operation.

In most prior art interrupting devices, the energy or current used to operate the device usually is not the same as the current to be interrupted. Again referring to a relay, the current used to drive the coil is generally not the same current flowing through, or interrupted by the plurality of contacts which are closed or opened, as the case may be, due to the energization of the coil of the relay. In a conventional relay, the current flowing through the contacts is completely unrelated to the current supplied to the relay's coil, thus requiring two different currents for normal operation.

Accordingly, it is an object of the present invention to provide a novel and simplified current interrupting device.

Another object of the present invention is the provision of a simplified current switching device, in which the current used to control the switching operation of the device is the same as the current to be switched thereby.

Another object of the present invention is to provide a novel current interrupting device utilizing a current-conducting liquid which is used to control the interruption of the current, as well as conduct the current therethrough between interruptions.

A futher object of the present invention is to provide a novel and simple current interrupting device in which liquid mercury is utilized as the current conducting medium for controlling as well as conducting the current to be interrupted.

These and other objects of the present invention are achieved in an arrangement wherein a capillary tube is filled with a current-conducting liquid. The capillary tube connected in series with an appropriate current load are connected across a source of electrical energy so that current flows through the electrical load as well as through the current-conducting liquid in the capillary tube. The current flowing through the liquid affects its electrical, as well as, physical characteristics. Consequently, the liquid parts at approximately the middle of the capillary tube, thus interrupting the flow of current through it, as well as, through the current load connected in series therewith.

When current flows through a current conducting liquid in a capillary tube, a constriction is provided near the middle of the tube, due to the "pinch" phenomena. This constriction increases the current density in the constricted area which produces greater forces in a direction which increases the constriction and also produces localized Joule heating as the constricted area has an increased resistance and a decreased capacity to conduct heat away from the area. As this process proceeds toward an increasingly smaller cross sectional area, it seems plausible that the Joule heating produces the break by vaporizing the small thread of current-conducting liquid bridging the main bodies of liquid. The arc immediately following the break also produces some vaporization. As the two bodies attempt to recombine the vapor has not completely condensed, and when the recombination occurs this gas is entrapped, forming an area of reduced cross section and thus higher-current density. This point then has a higher force acting on it to produce further constriction, and the cycle repeats, forming the rupture again in the same area.

During the periods that the two bodies of liquid are recombined, current flows through the liquid, as well as through the load connected in series therewith. However, during the interruption periods, current does not flow to either. It is thus seen, that the current used to produce the interruption is the same current to be interrupted. Namely, a single current is used to perform both functions. The changes in the current flowing through the load may be utilized to control a variety of circuits whose modes of operation are based on such current interruption phenomena.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1 is a schematic diagram useful in explaining the principles of operation of the current interrupter of the present invention;

FIGURE 2 is a simplified block diagram of one example of the application of the current interrupter of the present invention; and

FIGURE 3 is a simplified diagram of the second example of the use of the current interrupter of the present invention.

Reference is now made to FIGURE 1 wherein the current interrupter of the present invention designated **11** is shown connected in series with a current load **13** across a source of potential energy such as a battery **15**. The current interrupter **11** comprises a capillary tube **17** connected between reservoirs **19** and **21**, which are in turn

connected via electrodes 19E and 21E to the battery 15 and the current load 13 respectively. The reservoirs 19 and 21 are substantially filled with a current-conducting liquid 22, so that the capillary tube connected at the bottom of the two reservoirs is completely filled with such a liquid. The liquid may be mercury or any other liquid through which current may flow such as sodium, gallium or potassium.

As soon as the switch S1 is closed, current from the power sources 15 flows through the current interrupter 11 as well as through the current load 13. Such current tends to effect the current conducting liquid in the current interrupter 11, and in particular effects the liquid in the capillary tube 17. As current continues to flow through the current interrupter, the liquid in the capillary tube 17 heats up as a function of the value of current and resistive value thereof, until at some time a portion of the liquid at approximately the middle of the capillary tube. is converted into a gaseous form. As a result, an interruption of current occurs between two liquid surfaces which are separated by a given amount of gas trapped therebetween.

The interruption of current through the current interrupter 11, also interrupts the current flow through the current load 13 resulting in a sudden drop of the current flowing therethrough. Once the current no longer flows through the capillary tube 17, the gas trapped therein between the two liquid surfaces quickly condenses back into liquid form, thereby providing a new continuous path for the current to flow through the capillary tube. As a result, current flows again through the current interrupter 11 as well as the current load 13, until due to the new flow of current a portion of the liquid is again converted into gaseous form and thereby again interrupts the current flow therethrough.

From the foregoing, it is thus seen that in the current interrupter of the present invention, the current used to produce the interruptions, is the same on the current to be interrupted. Namely, the current supplied from the source 15, initially produces the current interruptions in the interrupter 11 by causing the liquid in the capillary tube to be converted into gaseous form, which in turn causes the interruption of the current. Thus, an arrangement is provided wherein the current which is being interrupted also produces the interruption effect.

By properly controlling the maximum current which may flow in the arrangement shown in FIGURE 1, as well as controlling the dimensions of the capillary tube, and in particular the diameter thereof for a given current conducting material a selected rate of interruption may be produced. For example, in one actual reduction to practice, a mercury-filled capillary tube 1" long and 0.010" in diameter was used to interrupt current in excess of 5 ampers at about 400 interruptions per second, with the current waveform being essentially a square wave.

The novel and simple interrupter of the present invention may conveniently be incorporated in any circuit where such current interruption is desired. For example, interconnecting it with a load such as the load 13 (FIGURE 1) a selected current therethrough may be interrupted at a predetermined rate. Similarly, the novel interrupter of the invention may be incorporated in a circuit for providing current which alternates at a selected frequency.

Reference is now made to FIGURE 2 which is a simplified diagram of a circuit 25 for providing an alternating-current (A.C.) signal from a D.C. source 27. The circuit includes the interrupter 11 connected in series with a variable load 29 between the source 27 and the primary winding 31 of a transformer 33, which is also connected to the source 27 through a switch 35. The secondary windings 37 of the transformer 33 are connected to a filter circuit 41, with the output thereof, designated by numeral 43, providing the desired A.C. output signal.

From the foregoing description, it is apparent that after closing switch 35 the D.C. current from the source 27 is interrupted in the interrupter 11, the rate of such phenomena depending on the dimensions of the interrupter as well as the current flowing therethrough, and the particular current-conducting liquid used thereon. Thus, by controlling the variable resistor 29, it is possible to control the value of the uninterrupted current flowing through the interrupter 11 and thereby control the rate of interruption. Namely, the frequency of the varying current flowing through the primary 31 may be controlled.

As is known by those familiar with the art, the frequency of the varying current in the primary windings 31, is reflected in the frequency of the varying current induced in the secondary windings 37 which, when filtered, may produce the sinusoidal A.C. signal 43. The frequency of the signal 43 is the same as the frequency of the varying current in the primary windings 31. Thus, by merely varying the value of the uninterrupted current flowing through the interrupter 11, lead 29 and primary windings 31, the frequency of the output signal may be controlled. Varying such current is most conveniently accomplished by changing the resistance of the load 29 which is in series with the interrupter 11 and windings 31.

The novel interrupter of the invention, due to its simplicity of operation is similarly incomparable in circuits for producing single pulses of predetermined characteristics rather than a continuously alternating signal, such as the A.C. signal 43 (FIGURE 2). For example, the interrupter of the invention may be incorporated in a circuit for producing single pulses, each of a predetermined time duration such as are produced by conventional one shot multivibrators.

Referring to FIGURE 3, there is shown a simplified diagram of another mode of operation of the interrupter of the invention. As seen, the interrupter 11 is connected in series with a variable resistor 47 and a resistor 49 across a D.C. source 51. A switch 53 is interposed between the source 51 and interrupter 11. An electrical load 55 is connected through a resistor 57 to the junction point between element 47 and 49. From the foregoing, it is apparent that upon closing switch 53 current flows through the interrupter 11 which, as a result, produces the interruption effect. The interruption of current occurs when some of the current conducting liquid is vaporized, which is due at least in part to the heating of the liquid by the power losses. Current starts to flow again after a portion of the vapor which is enclosed condenses again to provide a complete path for current flow.

The rate of condensation of the vapor may be controlled by encasing the interrupter within a temperature controlled unit 59 so that the temperature of the interrupter is controlled, thereby controlling the time required for the vapor to condense to liquid form. As a result, the time duration during which current does not flow is controlled, thus controlling the duration of a current signal 61 supplied through the resistor 57 to the load 55.

As long as the switch 53 is closed, the load 55 is supplied with a chain of signals, each of a duration controlled by the time required to vaporize the liquid and having an interval determined by the time required for the vapor in the interrupter 59 to condense to a liquid state. It is apparent, however, that a single pulse may be supplied to the load 55. This may easily be accomplished by causing the switch 53 to open after the first interruption occurs. Thus, a single interruption will produce a single pulse. Thereafter, a second signal may be produced by closing switch 53 to produce a subsequent interruption which, upon occurring, reopens the switch. Consequently, a single signal is produced each time the switch 53 is closed. The minimum duration between pulses is controlled by controlling the temperature of the interrupter, thereby controlling the time required for the vapor to condense to a liquid state.

Summarizing briefly, the novel current interrupter of

the present invention comprises a capillary tube filled with a current conducting liquid through which current is caused to flow. As a result of the current flow, the liquid, in addition to various phenomena taking place therein, heats up which vaporizes some of the liquid at about the center of the tube. Consequently, the flow of current through the liquid is interrupted. The current remains interrupted until the vapor condenses thereby again providing a current path through the liquid.

In such a novel arrangement, the current to be interrupted is used to also produce the interruption phenomena. When using any given current conducting liquid, the rate of interruptions as well as the duration of each interruption may be controlled by limiting the maximum current flowing through the tube as well as controlling the dimensions of the capillary tube and the temperature environment thereof.

The current interrupter may be incorporated in any switching or pulsing circuit in a manner similar to other conventional more complicated interrupting circuits or devices.

There has accordingly been shown and described herein a novel and useful apparatus for producing controlled current interruption. Modifications and equivalents may be introduced in the arrangements as shown without departing from the true spirit of the invention. Therefore, all such modifications and equivalents are deemed to fall within the scope of the invention as claimed in the appended claims.

What is claimed is:

1. A liquid current interrupter for interrupting at a selected rate the flow therethrough of current supplied thereto comprising a current-conducting liquid; a capillary tube filled with said current conducting liquid; and means coupled to said capillary tube for causing current to flow through said current-conducting liquid, and for interrupting the flow of said current, the rate of interruptions being at least a function of the properties of said current-conducting liquid, the magnitude of said current and the dimensions of said capillary tube.

2. A liquid current interrupter for interrupting at a selected rate the flow of current supplied thereto comprising a capillary column of current-conducting liquid; and means coupled to said capillary column for causing current to flow through said current-conducting liquid and for gasifying some of said liquid to interrupt the flow of current therethrough, the rate of interruptions being at least a function of the properties of said current-conducting liquid, the dimensions of said capillary column and the magnitude of said current.

3. A liquid current interrupter for interrupting at a selected rate the flow of current supplied thereto comprising a current conducting liquid; a capillary tube filled with said current conducting liquid; and means coupled to said capillary tube for causing said current to flow through said current-conducting liquid, and for converting at least some of said liquid to vapor so as to interrupt the flow of current therethrough, said vapor being contained within said capillary tube between said liquid, the rate of interruptions being a function of the properties of said current conducting liquid, the magnitude of said current and the dimensions of said capillary tube.

4. A liquid current interrupter for interrupting at a selected rate the flow of current supplied thereto comprising a current conducting liquid; a capillary tube filled with said current conducting liquid; and means coupled to said capillary tube for supplying said current to flow through said current conducting liquid, for converting at least some of said liquid to vapor to interrupt its flow therethrough until said vapor is condensed to liquid to thereby provide a subsequent continuous path for said current to flow therethrough.

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